Error Analysis and Selection of Optimal Excitation Parameters for the Sensing of CO_2 and O_2 from Space For ASCENDS Applications

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Abstract: Simulation studies to optimize sensing of CO_2 and O_2 from space are described. Uncertainties in line-by-line calculations unaccounted for in previous studies identified. Multivariate methods are employed for measurement wavelengths selection.

OCIS codes: (280.3640) Lidar; (300.6360) Spectroscopy, laser; (010.0280) Remote sensing and sensors;

1. Introduction

The Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS) recommended by NRC Decadal Survey has a stringent accuracy requirements of 0.5% or better in XCO_2 retrievals. NASA LaRC and its partners are investigating the use of the 1.57 µm band of CO_2 and the 1.26-1.27 µm band of oxygen for XCO_2 measurements.

As part of these efforts, we are carrying out simulation studies using a lidar modeling framework being developed at NASA LaRC to predict the performance of our proposed ASCENDS mission implementation [1]. Our study is aimed at predicting the sources and magnitudes of errors anticipated in XCO_2 retrievals for further error minimization through the selection of optimum excitation parameters and development of better retrieval methods.

2. Error analysis in line-by-line calculations

High accuracy of line-by-line simulations is required to meet the needed precision in XCO_2 measurements. It is determined by several factors including the precision of the atmospheric models used in calculations.

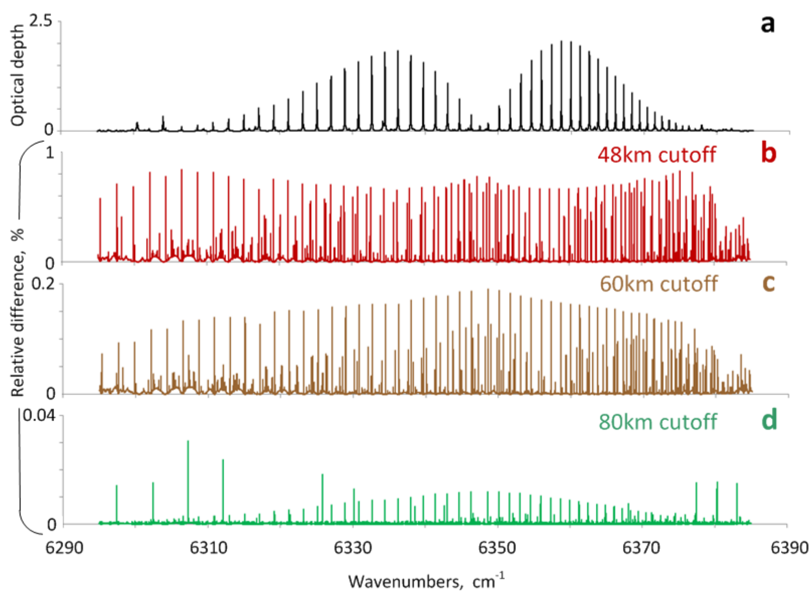

Fig.1 Effect of the atmospheric model cutoff altitude on the accuracy of line-by-line calculations for the CO_2 molecule in the 1.57 µm band (**a** – CO_2 optical depth spectrum calculated using the LBLRTM program (Version 12.0) for a vertical path length form the ground to 120 km; Relative difference between the calculated optical depths for: **b** – cutoff altitude of 48 km (CTM model limit) and 120 km, **c** – cutoff altitude of 60 km (MERRA 42-level grid) and 120 km, **d** – cutoff altitude of 80 km (MERRA 72-level grid).

For example, the previous simulation studies by Kawa et. al. relied on the use of the LBLRTM program and the HITRAN 2008 database with atmospheric model parameters (pressure, temperature, humidity, CO_2 concentration) fields supplied by the Chemistry Transport Model (CTM) with a pressure level grid maximum cutoff altitude of 48km (1 mb) [2 - 4]. Fig. 1 shows a comparison of calculations performed using the LBLRTM program and the HITRAN 2008 database using built in Tropical atmospheric model for different cutoff altitudes of 120 km, 80 km, 60 km, and 48 km. As can be seen, the relative difference due to the low cutoff altitude of 48 km corresponding to the altitude limit of the CTM model may reach as much as 0.85% in optical depth values possibly limiting the retrieval accuracy of the CO_2 concentrations. Also shown are the calculations using the MERRA 42-level grid with a higher maximum altitude of ~60km resulting in an uncertainty of ~0.2%, and the 72-level MERRA grid with a maximum cutoff altitude of 80 km.

Other factors being considered in our calculations are the accuracy of initial spectral data and the precision of the lineshape models used. Our previous comparative analysis has shown that the additional uncertainty in the line-by-line spectral parameters provided in HITRAN 2008 as compared to more recent publications may result in optical depth calculation differences for the 1.57 µm band of CO_2 of up to 0.7% [1, 5 -7]. The above factors combined with the ~0.5% accuracy limitations of the Voigt profile lead to an estimated total additional error of up to 1.2% in the measurement accuracy of CO_2 alone [8].

Similar error analysis is being conducted for the 1.26 micron band of O_2 which is used for total pressure measurements required for the XCO_2 retrieval. Comparative simulations for alternative CO_2 2.05µm and A-band of O_2 are planned.

We also investigate the use of multivariate data analysis on the results of the simulations to establish optimal excitation wavelength combinations providing better retrieval accuracy throughout the multitude of seasonal and geographical variations in environmental parameters.

3. Conclusions

Our preliminary analysis of the line-by-line calculations for CO_2 indicate previously unaccounted for errors in excess the 0.5% precision sought for in the ASCENDS mission XCO_2 measurements. To minimize these and similar errors all factors contributing to the final accuracy of line-by-line calculations have to be addressed (e. g. spectral data accuracy, lineshape models including line mixing and collision broadening, accurate atmospheric models). Our analysis of these and additional instrumental uncertainties limiting the accuracy of CO_2 and O_2 retrievals and possible ways of minimizing such errors will be presented. Comparative studies to evaluate the accuracy achievable through the use of alternative lineshape models are planned.

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5. References

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